Desalination and Water Treatment
www.deswater.com
doi:10.5004/dwt.2018.22553

116 (2018) 342–348
June

Evaluation of Al-Shamiyah River water quality using the Canadian Council of Ministries of the Environment (CCME) water quality index and factor analysis

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Received 23 December 2017; Accepted 27 May 2018

ABSTRACT

Canadian Council of Ministries of the Environment Water Quality Index (CCME WQI) was used to determine Al-Shamiyah River water quality and its suitability for aquatic life. To calculate CCME WQI, a set of sixteen water quality parameters were evaluated: water temperature (W.T), turbidity (Tur), total dissolved solids (TDS), pH, dissolved oxygen (DO), the biological oxygen demand (BOD5), chlorides (Cl), nitrite (NO_2), reactive nitrate (NO_3), reactive phosphate (PO_4), and dissolved heavy metals (cadmium, copper, chromium, zinc, manganese, lead). In addition, water samples were collected monthly from four sites along Al-Shamiyah River during the period from March 2013 to February 2014. According to CCME WQI analysis, the water quality of Al-Shamiyah ranged from 70.1 to 84.47 at the studied sites, which is considered "Fair–Good",and was well above the "Marginal" class. The quality of the water is at a desirable level. The water quality seems unaffected by any pollutants that may have entered the river, and it remains at a quality necessary to sustain diverse and sensitive aquatic life. The results of PCA reflected a good look on the water quality monitoring and interpretation of Al-Shamiyah River water.

Keywords: Lotic ecosystems; CCME WQI; Water quality index; Al-Shamiyah River; PCA

1. Introduction

Fresh water is essential to sustain terrestrial life on the earth, though water quality of streams in rivers in many places is affected by human activity. The need for water quality monitoring programs has increased as sources of pollution from human activity increases [1,2]. Water quality can be characterized by the physicochemical and biological characteristics that affect the aquatic organism's growth and the qualities desired for the water, which may include utilization for human uses such as irrigation and drinking water [3]. The process for determining water quality of any water body depends on the traditional evaluation of environmental factors, and how they compare with local and international standards [4]. Therefore, water quality indices have been used to achieve an effective and comprehensive approach for the management of water quality. These indices are mathematical equations used to analyze a large number of water quality parameters. These parameters are derived from replicated tests for a range of physical and chemical factors to sample the water and should provide context for the collected measures, such as a scale from poor to excellent quality [5–7].

As the use of the water quality index and the ability to apply it to any water body helps determine its nature in terms of the purity and pollution, this also helps evaluate potential uses of the water [8].

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Water quality index (WQI) is a tool to reflect the composite influence of different water quality factors. WQI is a fast and simple manner to explain and summarize water quality data in an expressible and understood format [9]. Therefore, in this study, the water quality of Al-Shamiyah River was tested by the Canadian Council of Ministries of the Environment water quality index, (CCME WQI) which can be considered as one of the simplest methods to test the water quality status [10,11].

The CCME WQI is well accepted, flexible and applicable model for testing the WQI and can take assess a large number of water quality variables. However, the calculation requires that at least four variable sampled a minimum four times be used [12].

2. Materials and methods

The Al-Shamiyah River enters the borders of Al-Diwanyiah province on the north-west side after dividing from the Al-Hindiya River (Euphrates River) to the Al-Shamiyah River and Kufa River south of the Kifil city, in the middle region of Iraq. Its length is (120 km) and the discharge capacity 180 m^3/S. Up to the 384,000 acres of land is irrigated by this river (Fig. 1). The surface water resources represented by Al-Shamiyah River are the main source of water for agricultural activity in the study area, and the drinking water of many villages. Four sites were selected along the river. Site 1 is selected on the Shamiyah River after branching the Euphrates River to the Kufa River and Al-Shamiyah River at longitude (eastwards) (44°36′68″) and latitudes (northwards) (32°18′53″). This site will be recognized by the higher level of water in the river in this site and some species of aquatic plants with remarkable intensity such as *Phragmites australis, Typha domengensis, Ceratophyllumdemersum, Potomogetonpectinatus*. It is also characterized by a widening area and has minimal human and agricultural activity on both sides of the river. Site 2 is located in the area of Al-Abbasiyah in the Al-Salihiya township at longitude (eastwards) (44°53′83″) and latitudes (northwards) (32°04′ 45″). The river water in this site is under the influence of agricultural activity and a small impact of population, this site contains the same aquatic plants as Site 1. Site 3 located within a populated area in the district of Al-Shamiyah, at longitude (eastwards) (44°62′40″) and latitudes (northwards) (31°83′92″), and there is much agricultural activity in the area, with similar aquatic plants as site 1 and 2. Site 4 was at Ghammas town, at longitude (eastwards) (44°55′39″) and localities (northwards) (31°63′92″), with abundance agricultural activity surrounding the river at this point.

For the geological and climatic nature of the study area, Al-Shamiyah River extends within the sedimentary formations, which is one of the most important formations of the quaternary era (the Pleistocene) and the most recent formation and geology. It is caused by the delta of the Tigris and the Euphrates and the valleys that descend from the western plateau. The sediments of this age are the source of gravel, sand and sediments, which in most cases are the direct source of agricultural soil.

Al-Shamiyah River was selected for applying the water quality index (CCME.WQI). Monthly sampling was taken from four sites along Al-Shamiyah River during the period from March 2013 to February 2014. All physicochemical parameters and heavy elements (cadmium, copper, chromium, zinc, manganese, lead) were analyzed following methods outlined in the standard method for examination

Fig. 1. Location of sites on Al-Shamiyah river.

of water and wastewater [13]. The calculation of (CCME WQI) Depending on the detailed formulation of CCME WQI, as described in the Canadian WQI 1.0– Technical Report [12]. The detailed formulation of CCME WQI is as follows:

$$\text{CCME WQI} = 100 - \left[\sqrt{\frac{F_1^2 + F_2^2 + F_3^2}{1.732}}\right] \quad (1)$$

The calculation is constructed on three factors: F_1 (scope) which represent the extent of water quality guideline non-compliance over the time period of interest, while F_2 (frequency) is defined as the number of times that the guidelines are not respected, and F3 (amplitude) which is defined as the difference between noncompliant measurements and the corresponding guidelines.

The factor of 1.732 arises because each of the three individual index factors can range as high as 100.

The term F_1 (scope) expresses the percentage of parameters for which at least one measurement did not comply with the corresponding guideline during the period under study:

$$F_1 = \left[\frac{\textit{number of failed variables}}{\textit{Total number of variables}}\right] \times 100 \quad (2)$$

The term F_2 (frequency) represents the percentage of analytical results that do not comply with the guidelines.

$$F_2 = \left[\frac{\textit{number of failed test}}{\textit{Total number of test}}\right] \times 100 \quad (3)$$

F_3 (amplitude) represents the *difference* between the non-compliant analytical results and the guidelines to which they refer. The term F_3 is an asymptotic function, representing the normalized sum of excursions (*nse*) in relation to guidelines within the range of values from 0 to 100.

$$F_3 = \left[\frac{nse}{0.01nse + 0.01}\right] \quad (4)$$

To calculate the overall degree of noncompliance, we add the excursions of noncompliant analytical results and divide the sum by the total number of analytical results. This variable is called the normalized sum of excursions (*nse*).

$$\text{nse} = \frac{\sum_{i=1}^{n} \textit{excursion}}{\textit{Number of test}} \quad (5)$$

There are two possible ways of determining the excursion:

When the test value must not exceed the objective:

$$\text{excursion} = \left[\frac{\textit{Failed test value}}{\textit{Objective}}\right] - 1 \quad (6)$$

When the test value must not fall below the objective:

$$\text{excursion} = \left[\frac{\textit{Objective}}{\textit{Failed test value}}\right] - 1 \quad (7)$$

The identification the water quality of Al-Shamiyah River water depending on the following categories in (Table 1) [12]. SPSS program was used for statistical analysis of obtained date, while Principal Component Analysis (PCA) was applied to assess correlations among water quality variables.

3. Results and discussion

Physicochemical results were ranged as follows: water temperature (11.33–36.00°C), turbidity (8.25–22.11 NTU), total dissolved solids (709–998 mg/L), pH (7.46–8.23), dissolved oxygen (6.30–10.50 mg/L), biological oxygen demand (0.99–2.50 mg/L), chloride (47.43–123.33 mg/L), nitrite (0.16–2.20 µg/L), nitrate (40.38–117.46 µg/L), phosphate (0.012–0.22 µg/L). Heavy metal concentrations (dissolved phase) ranged (0.05–1.44 µg/L), (1.57–7.25 µg/L/l), (0.00–1.70 µg/L), (0.02–1.33), (0.08–2.74 µg/L) and (0.44–1.84 µg/L) for copper, manganese, cadmium, lead, zinc and chromium respectively (Table 2). The variations in the concentration of the dissolved heavy metals may be related to the water drainage and household waste and agricultural drifts down to the river water, which vary from site to site and from season to season, and due to the difference in using fertilizers to enrich the neighboring lands and water drainage areas of the river that pass by it without prior treatment so increase the concentration of the dissolved heavy elements differed significantly [14].

The calculated values CCME WQI of Al-Shamiyah River ranked between fair in stations 1, 2 and 4 to good in station 3 (Table 3). Thus, these results may due to environmental factors involved to calculate the WQI being within the acceptable ranges [14]. However, the water quality of the Al-Shamiyah River in August has been observed to be (moderate) in sites (1, 2 and 3) and WQI values reported, as (70.1, 73.34 and 73.31) respectively, while in the fourth site was in September the WQI values were reported as (73.72). The results showed that the water quality in Al-Shamiyah River in the first site to be a good estimate during the April (84.45) and in the second and third site a good rating (84.34 and 84.47) respectively, the fourth site has received a value (84.42) in January (Table 4, Fig. 2). The lowest rate in Al-Shamiyah River to water quality was (79.11) in the second site and the highest rate (80.39) in the third site.

In the first site water quality characterized as "Fair" during March, June, July, August, September, October, December and February. While water quality characterized as "Good" during April, May, November and January. However, the results showed the water quality in the second site will be acceptable (Fair) during April, May, June, July, August, September, October and February. The

Table 1
Categorization of water quality

Rank	WQI Value
Excellent	95–100
Good	80–94
Fair	65–79
Marginal	45–64
Poor	0–44

Table 2
Physiochemical parameters through study period and the standers determinants by CCME [15] suitable for aquatic life

Parameters	Range	Standers determinants by CCME suitable for aquatic life [15]
Water temp. (°C)	11.33–36.00	15
pH	7.46–8.23	6.5–9
Turbidity (NTU)	8.25–22.11	5
TDS (mg/L)	709–998	500
DO (mg/L)	6.3–10.5	5.5–9
BOD5 (mg/L)	0.99–2.5	≯3
Chloride (mg/L)	23.33–47.43	250
Nitrite (µg/L)	0.16–2.2	60
Nitrate (µg/L)	40.38–17.47	13000
Phosphate (µg/L)	0.012–0.22	100
Copper (µg/L)	0.05–1.44	2
Manganese (µg/L)	1.57–7.25	100
Cadmium (µg/L)	N.D–1.70	0.2
Lead (µg/L)	0.02–1.33	7
Zinc (µg/L)	0.08–14.02	30
Chromium (µg/L)	0.44-1.84	1

Table 3
Mean ±(SD) for CCMEWQI of sites through study period

Site	CCME WQI values
1	79.19 ± (4.68)
2	79.11 ± (4.47)
3	80.38 ± (5.15)
4	79.57 ± (3.53)

Table 4
Monthly values of water quality index (CCME WQI) for the purpose of aquatic lifein Al-Shamiyah River during the study period 2013–2014

Months	Sites			
	S1	S2	S3	S4
March 2013	79.23	84.34	84.47	79.22
April 2013	84.45	79.35	79.5	79.23
May 2013	84.15	79.04	84.14	78.94
June 2013	73.5	74	73.44	79.05
July 2013	79.04	73.91	74.05	79.08
August 2013	70.1	73.34	73.31	73.82
September 2013	79.2	79.06	73.85	73.72
October 2013	74.11	74.07	84.37	84.26
November 2013	84.21	84.31	84.37	84.35
December 2013	79.17	84.33	84.44	79.39
January 2014	83.99	84.27	84.32	84.42
February 2014	79.18	79.25	84.37	79.34
Average	79.19	79.11	80.39	79.57

third site, the months during which the quality of river water Al-Shamiyah got a reasonable estimate (Fair) were April, June, July, August and September. While the months got a good estimate on this site are March, May, October, November, December, January and February). In the fourth site the months that got the water that estimates acceptable quality (Fair) was March, April, May, June, July, August, September, December and February, while the months that got water quality was "Good" was October, November and January. It can be noted that Al-Shamiyah River water quality may be fact acceptable (Fair to Good) in some months due to the fact that the variables which go into calculating the quality of water did not exceed the required standards [12].

The cause of the deteriorating water quality is most likely due to the increasing population growth and advanced human activities such as land use existing agriculture around the river and as the waste product from these activities, which is poses to the river [16]. While exposing the water to the deterioration and decline to the level of Marginal, any that water exposed to pollution and in most cases away from the ideal, or to the level of Poor as the water pollution away from ideal at all times (Table 1).

Water quality deterioration in the current study depends on the quality of the effluent and raised to the river, which varies from one location to another and from one month to another [17]. In addition, the changes in water quality occurs either by natural factors or due to human activities [18]. The increasing in population density, land use, which located around the river basin and used for agriculture leads to deteriorate of water quality in the river [19].

Increased of agriculture and other human activities cast their waste into the river affected the quality of water and the volatility of Good to Fair [20]. Nevertheless, the water quality deteriorates because of what raises it from municipal waste and waste resulting from the agricultural field from around the river [21].

The variables that go into calculating WQI, which exceeded the standard calibrator, were TDS and turbidity, while temperature and heavy metals (cadmium and chromium) exceeded the standard calibrator in some samples. This may reflect the effect of pollution from urban wastes and anthropogenic activities [6]. The reason may also be due to an increase in some variables that go into calculating the water quality, especially the temperature of the water, which was highly variable in daily and monthly temperature [22]. In addition, it may be due to the difference in climatic conditions, which increase the intensity of solar radiation on the surface of the water [23]. The turbidity may have also played a large role. When water levels are high, turbidity tends to increase as water volumes and the speed of flowing water increase, resulting in larger sized particles becoming suspended in the water column. However, the high value of the turbidity may be related to the sewage put into the river and that contain large amounts of organic materials and inorganic and sand and microbiology [24], and from domestic sewage water and runoff from the agricultural land near the banks of the river [25].

When comparing the results of water quality in Al-Shamiyah River which ranging from Fair to Good with other studies, it can be noted that, it is better than the quality of the Tigris River, which ranged between Marginal and Fair [26]. Similar to the water quality of Shatt Al-Arab River, turbidity and TDS are the major factors that affected the water quality [27].

The water quality of Al-Shamiyah River that ranged between the two categories (Fair-Good) better than the waters of the Euphrates River in the area between Heet and Al-Ramadi (Poor–Marginal), which can primarily be attributed to variations in urban and industrial pollution around the catchment of these two rivers [28].

The results of CCME WQI in the current study is consistent with those of Hassan and Shaawiat, [29] reporting that the environmental factors and the biodiversity indices showed that Al-Shamiyah River water quality is considered moderately polluted to the clean water. Applying the CCME WQI model on the Iraqi environment well show the actual water quality status [30–32].

Using SPSS program the statistical analysis of the results showed a positive correlation between water quality index (CCME WQI) and some environmental factors: turbidity (Tur), pH, total dissolved solids (TDS), dissolved oxygen, biochemical oxygen demand (BOD5), nitrate (NO_3), and chloride (CL). The highest correlation between water quality index was recorded with pH and dissolved oxygen (D.O) (R = 0.98 and R = 0.94) respectively, and lowest values of water quality index correlation was recorded with nitrate (R = 0.53) (Fig. 3).

PCA analysis (Fig. 4) showed the positive and negative correlations. The first axis showed the positive correlation between PO_4 and Cl, while the second axis shown the positive correlations between Tur, NO_3 and DO, and in the fourth axis shown the positive correlation between BOD5, TDS, NO_2, W.T. In addition, the negative correlations were recorded between the variables in the third axis, and the variables in the second axis were correlated with the variables the fourth axis.

4. Conclusion

The deterioration of water quality due to a change in the physical and chemical factors because of pollution it is often slow and not easy to be seen. However, the Canadian Council of Ministries of the Environment Water Quality Index (CCME WQI) was used to evaluate the water quality in Al-Shamiyah River and the results indicated that the quality of water was ranged between the two categories (Fair and Good). The results of the current study also

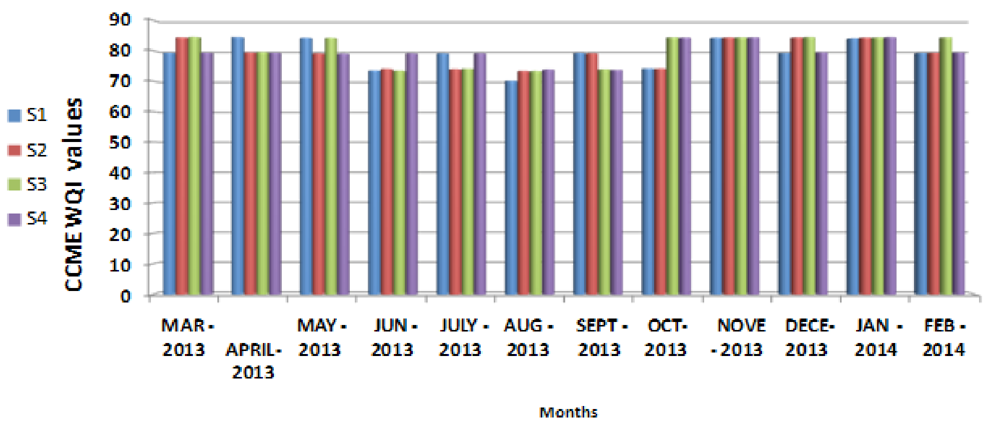

Fig. 2. Monthly values of water quality index (CCME WQI) for the purpose of aquatic life in four sites in Al-Shamiyah River during the study period 2013–2014.

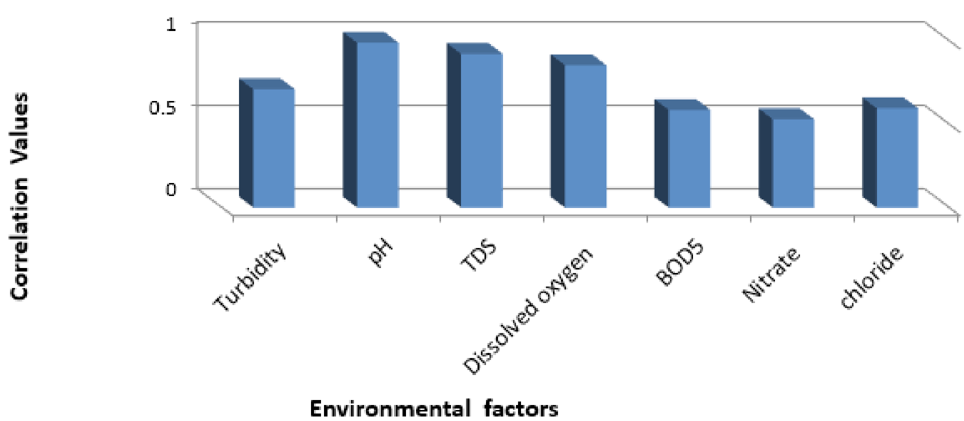

Fig. 3. The correlations between water quality index (CCME.WQI) and some environmental factors.

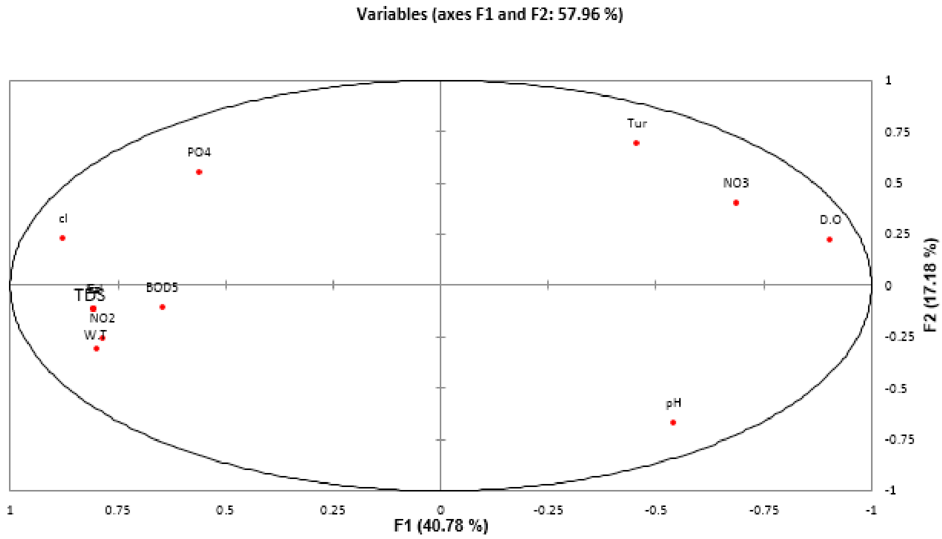

Fig. 4. PCA analysis of some environmental factors.

indicated the reflection of various types of pollutants that enter the river, which date back to various human activities in the study sites, and from domestic sewage water and runoff from the agricultural land located near the banks of the river, which may be responsible for the variation in the water quality.

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